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A WRF-based Weather Running Estimate-Nowcast Tool for Army Applications

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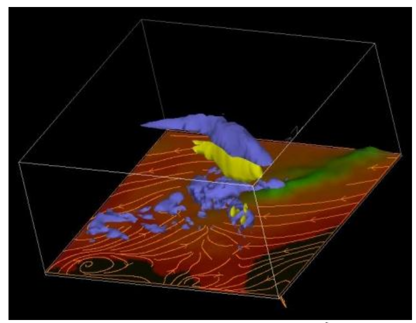
WEATHER RUNNING ESTIMATE - NOWCAST (WRE-N) FOR ARMY

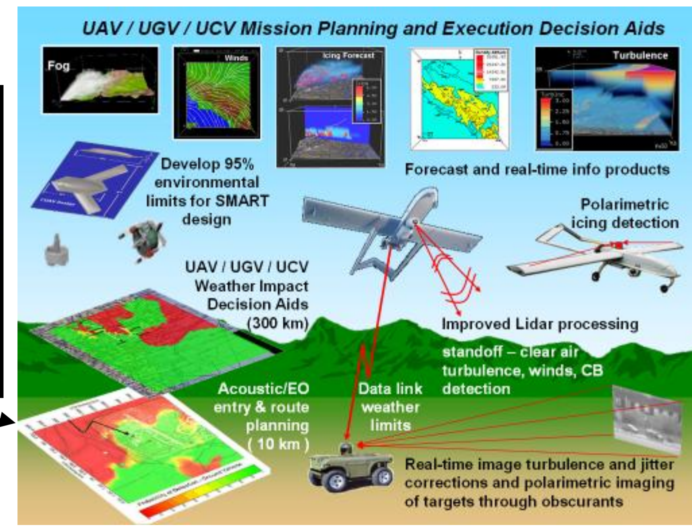
- The frequent updating of local environmental "data cubes" for use by Army & Air Force tactical weather systems (IMETS/JET, DCGS-A, FCS) and decision aids, to improve tactical execution strategy, situational awareness, and decision making

- A dynamic ability to adjust local environmental data cubes to the real and evolving weather

TUAV with TAMDAR



WRE-N



Execution Decision Aids

WRE-N is designed to provide local corrections to the regional forecast data cube along with Army-required finer scale domains & resolutions.

*effectively, WRE-N is a storm-scale rapid-update cycling system

WRE: The "0 h" analysis

Nowcast: The forward prediction out to 3-6 h

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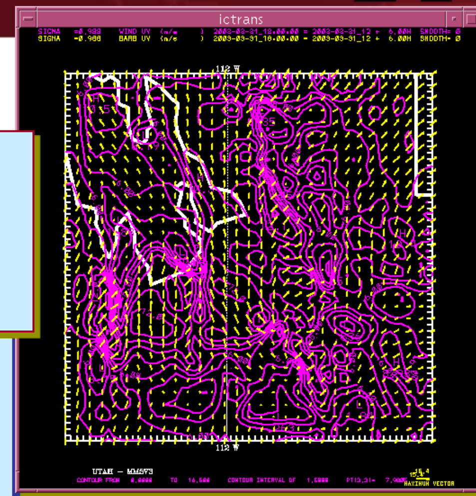
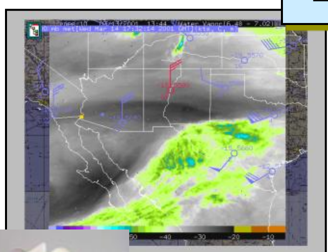
Hierarchy of models for high resolution updates to forecasts

Forecast - Operational Center (AFWA) meso/global NWP Forecast for next 24-72 hours, 4 times daily, up to 5 km (or even 1.67 km) finest resolution and on a larger grid domain

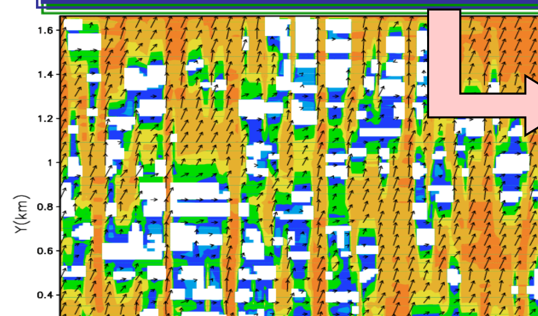
Local short term nowcasts at BCT (DCGS-A) or for Artillery Met



Nowcast (short term forecast) - rerun hourly, to provide predictive nowcasts out 3-6 hours onto a finest <= 1 km mesh over ~ 100 x 100 km or domain (WRF ARW)



Weather Running Estimate (WRE) – The "0-h" condition produced every 60 minutes on a <= 1 km mesh for ~ 100 km x 100 km domain by ingesting local & non-traditional observations (UAV sensors, sfc wind sensors, artillery sondes, profilers, etc) via the FDDA observation nudging feature of WRF-ARW (3 h FDDA period)



Diagnostic High Resolution Models – fast running (5-10 min) boundary layer wind model at 10-100 m resolution for complex and urban terrain effects on average wind flow – can use local observations

Provides input to advanced applications on DCGS-A.

Local WRE analysis assimilates data at BCT (DCGS-A)

ARL 3DWF Diagnostic urban wind model running as embedded client on BCT DCGS -A

WRF-ARW Nesting Configurations for WRE-N

AFWA and NCEP operational models now running to unprecedented horizontal and temporal resolutions:

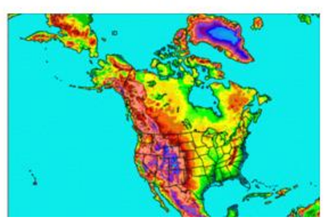
- AFWA running 5 km MOAD (with WRFVAR- soon to be GSI) and 1.67 km subnest over large regional areas: 6 h cycles run at 12z, 18z, 00z, 06z

- NCEP NAM (ie; WRF-NMMB) to about 13 km with GSI & 4x daily , along with Rapid Refresh capability hourly (with high resolution nest to 3 km)

~May 2011 NAM Upgrade

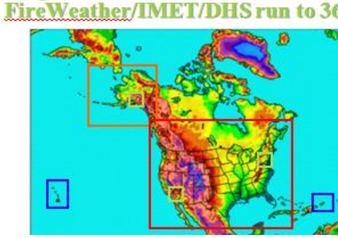
Current NAM

- WRF-NMM (E-grid)
- GSI analysis
- 4/Day = 6 hr update
- Forecasts to 84 hours
- 12 km horizontal
- 12 hr pre-forecast assimilation period with 3hr updates (catch-up)



New NAM

- NEMS based NMMB
- B-grid replaces E-grid
- Parent remains 12 km to 84 hr
- Multiple Nests Run to 60 hr
  - 4 km CONUS nest
  - 6 km Alaska nest
  - 3 km HI & PR nests
- Single locatable ~1.33-1.5 km FireWeather/IMET/DHS run to 36hr



*Geoff DiMego , NCEP 8 Dec 2010

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WRF-ARW Nesting Configurations for WRE-N

WRE-N configurations being tested by ARL using WRF-ARW observation nudging FDDA

For applications that can be run either at AFWA or at an Army Brigade Combat Team level in the Distributed Common Ground System-Army (DCGS-A)

source	WRE-N
AFWA WRF-ARW 5 km	[3 km/ 1 km] nesting- 500 km x 500 km outer domain
AFWA WRF-ARW 1.67 km	[0.5 km] nest- 100 km x 100 km (or larger) domain

Goal is to cycle WRE-N hourly, but is observation, application & hardware dependent. We have tested hourly, 3-hourly & 6-hourly FDDA cycling including use of WRF restart feature

For applications that can be as an Artillery Met next-generation profiler model

source	WRE-N
GFS 0.5 deg or UM 25 km	[9 km/3 km/1 km]- 1750 km x 1750 km outer domain
	[15.75 km/5.25 km/1.75 km]- 1750 km x 1750 km outer domain
	[13.5 km/4.5 km/1.5 km/ 0.5 km]- 1750 km x 1750 km outer domain

* Artillery nest configuration eventually driven by computer hardware selection & required size and resolution of finest nest domain (although it will probably need to be < 2 km grid spacing)

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Hourly data assimilation cycling concept for a full-physics WRE-N at cloud-to-storm scales

ARL

Local obs from the last 180 min prior to the desired analysis time

AFWA 5 km WRF-ARW for LBCs

WRF-ARW observation nudging for local four-dimensional data assimilation (FDDA) 3 h preforecast period

New "spun up" initial condition for WRF-ARW

WRF-ARW model 3 h "nowcast" prediction

Nesting to achieve 1 km grid spacing for 100 km x 100 km region (even finer for smaller inner nests such as 300m in possible future versions):

Current:

(i) 3 km/1 km (outer nest: 500 km x 500km, inner nest: 100x100 km)

*** WRF-ARW is core prediction module in WRE-N**

The new WRF-ARW forecast will be used as the first guess background for the next hourly cycle

Refreshed high resolution data cube over local AOI for next 3 h

- **run hourly WRE-N cycling within AFWA's operational WRF-ARW system (5km grid spacing)**
- **cold-start WRE-N cycling system once every 12 or 24 h , and then use WRF "restart" to self-cycle thereafter**
- **make use of local & non-traditional battlefield obs that will not be included in AFWA cycling**

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"Non-traditional" weather observations possible in FCS for WRE-N

***Model*, e.g.**

WRF-ARW via AFWA

***Surface Data*:**

Mesonet/ special Army sfc weather obs

METAR/SYNOP

Local sensors (such as hosted from mobile UGVs)

***Aircraft data*:**

UAV sensor obs (such as TAMDAR)

***Upper air data*:**

raob (artillery)

Dropsonde

Airborne lidar wind profiles

Asynoptic & sporadic nature of these obs (most which will be boundary layer) appear to make the continuous DA approach of FDDA observation nudging attractive

Direct use of satellite radiances in WRE-N unlikely, beyond their use in the mesoscale AFWA WRF-ARW data assimilation system used for the WRE-N cold start & lateral boundary conditions. Future hybrid FDDA + 3DVAR might make them useful in WRE-N.

GOAL: Assimilate synoptic & non-traditional sources of local battlefield weather data (those data not used in AFWA data assimilation cycling) to derive the best current local AOI weather depiction at frequency of every hour → for WRE-N and Weather Decision Aid use.

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Hybrid WRE-N

-Observation nudging FDDA- allows continuous assimilation of asynoptic direct obs

-Variational 3DVAR (WRFVAR or LAPS)- could be used for producing intermittent analyses ingesting indirect observations- volumetric radar (radial wind,reflectivity), volumetric lidar (radial wind), satellite radiance, etc.

-Analyses nudging- used to "nudge model fields to variational analyses, in unison with continuous observation nudging FDDA

*Challenges: preprocessing and QC of radar data before using in variational system, assignment of background errors for 3DVAR, observation weights for nudging , and balance condition for storm scale (again, for 3DVAR)

Could LAPS/STMAS potentially fill the need of (1) serving as the VAR package in the hybrid WRE-N, especially for radar/lidar assimilation and/or (2) serving as an independent source of gridded ground truth data at storm-scale (0.5-3 km) for our WRE-N evaluation case studies using GridSTAT and MODE /MODE Time-Domain in MET?

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BACK UP SLIDES

WRE-N research examples

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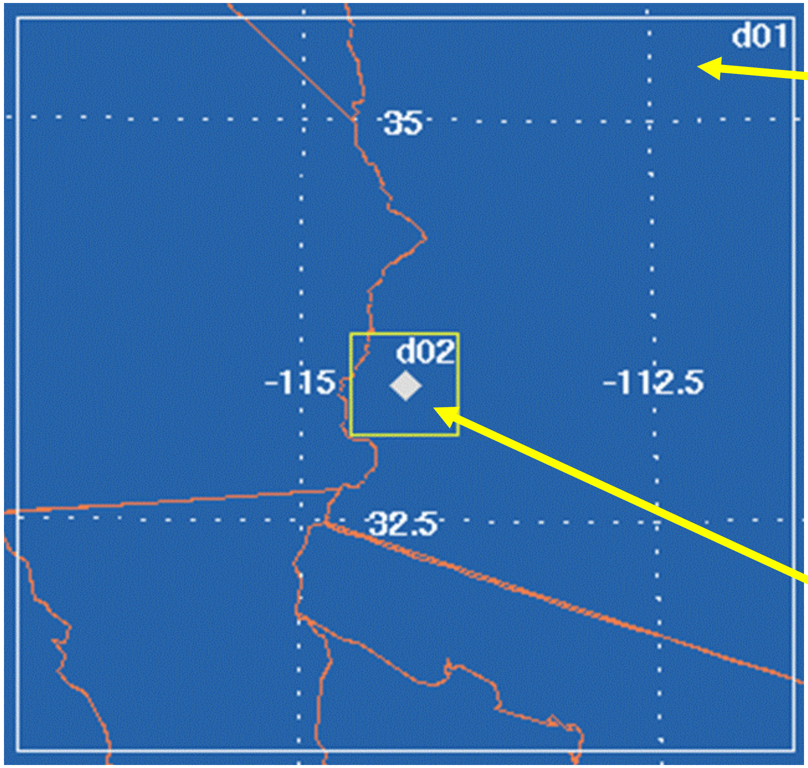
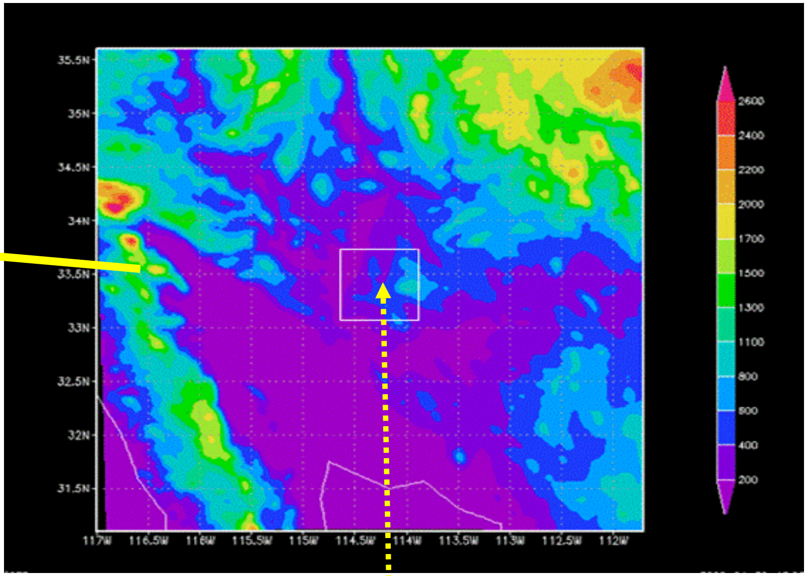
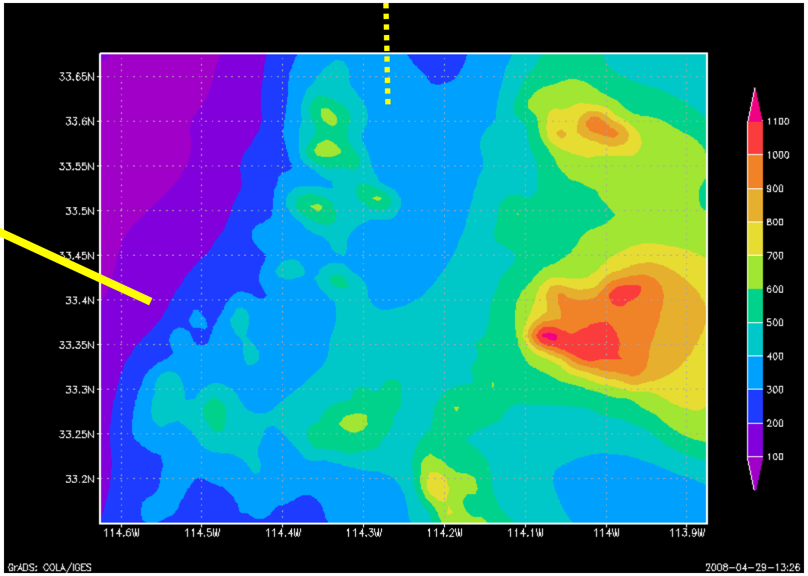
WRE-N FDDA experiments with observation nudging of YPG

WRE-N domain as configured for the CRREL YPG ScanEagle project, using WRF-ARW





3 km inner WRF nest



1 km inner WRF nest

3 km nest: 171x171x60

1 km nest: 73x73x60

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WRE-N FDDA experiments with observation nudging of YPG

Experiment	Description
LGRAD	radii of influence for all obs domain 1 = 120 km, domain 2 = 40 km
HLRAD	radii of influence for UA obs remains same but surface obs 60 km, 20 km
SMRAD	radii of influence for all obs domain 1 = 60 km, domain 2 = 20 km
HSRAD	radii of influence for UA obs remains same but surface obs 30 km, 10 km
DFRAD	radii of influence for all obs set to 18 km, 6 km
STATIC	same as HLRAD but with fixed time step of 9 sec for domain 1, 3 sec for domain 2
COLDS	same as STATIC but with no FDDA

- 7 experiments with varied sized radii of influence for FDDA
- 24 hr simulation: 06Z 30 November - 06Z 1 December 2007
- 12 hr FDDA followed by 12 hr free forecast

WRE-N FDDA experiments with observation nudging of YPG

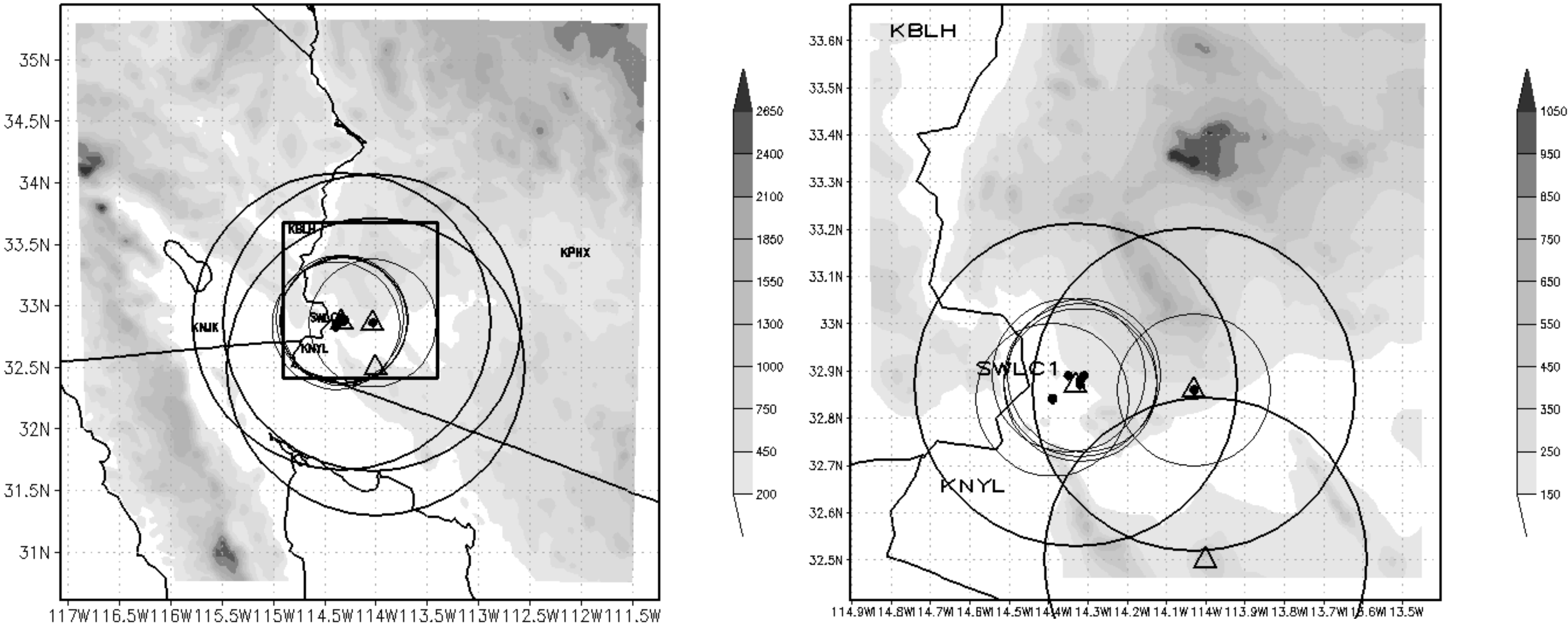

Figure 1: Domain configurations for (a) domain 1 and (b) domain 2. Assimilated observations are represented as circles (surface stations) and triangles (radiosondes) and their radii of influence are approximated by the open circles with radii equal to 120 km and 60 km in (a) and 40 km and 20 km in (b). Verification stations are also labeled with 4-letter station ids. Location of domain 2 in (a) represented by box.

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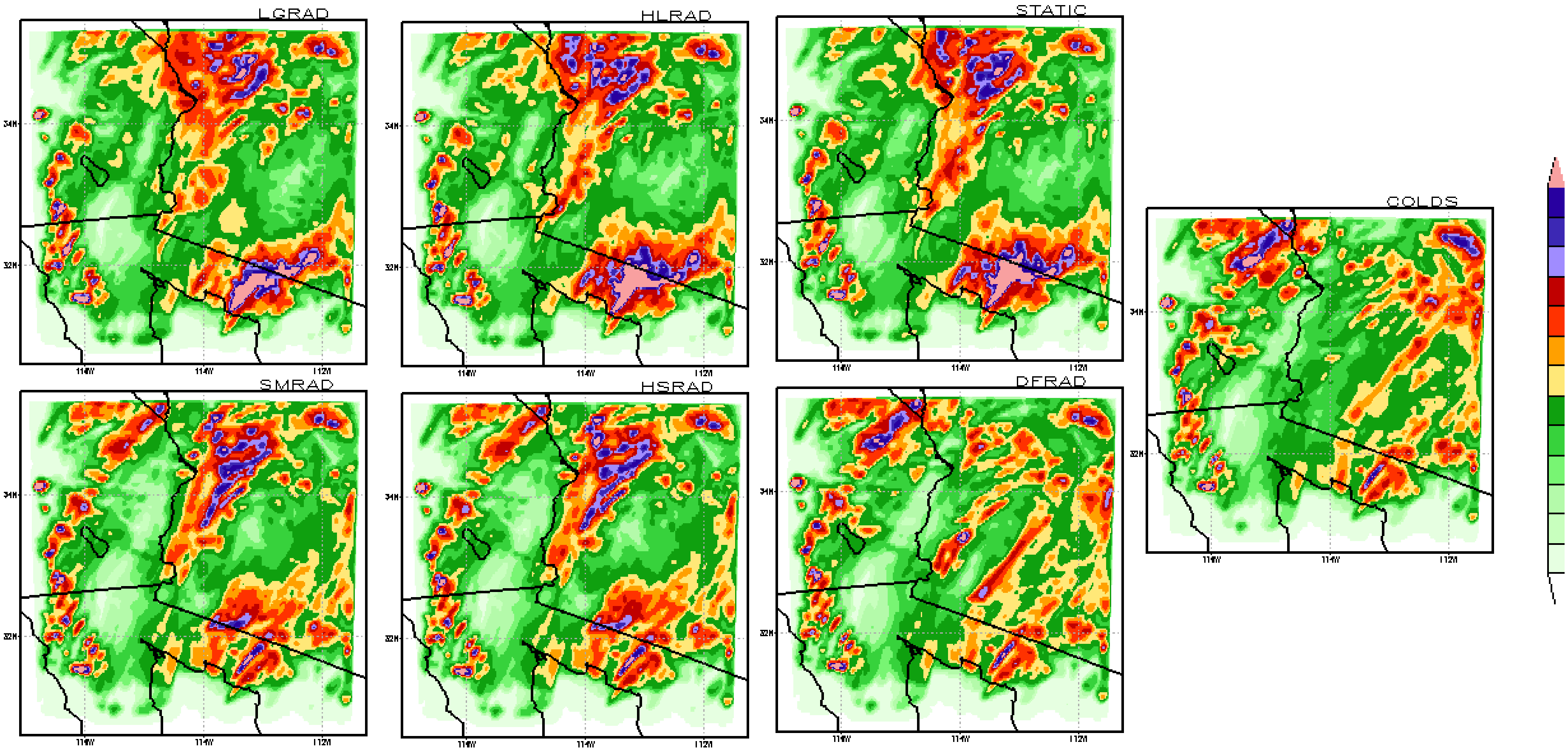
WRE-N FDDA experiments with observation nudging of YPG



Experimental 24-h accumulated precipitation for the entire simulation over domain 1 (3 km). Experiment labels top right .

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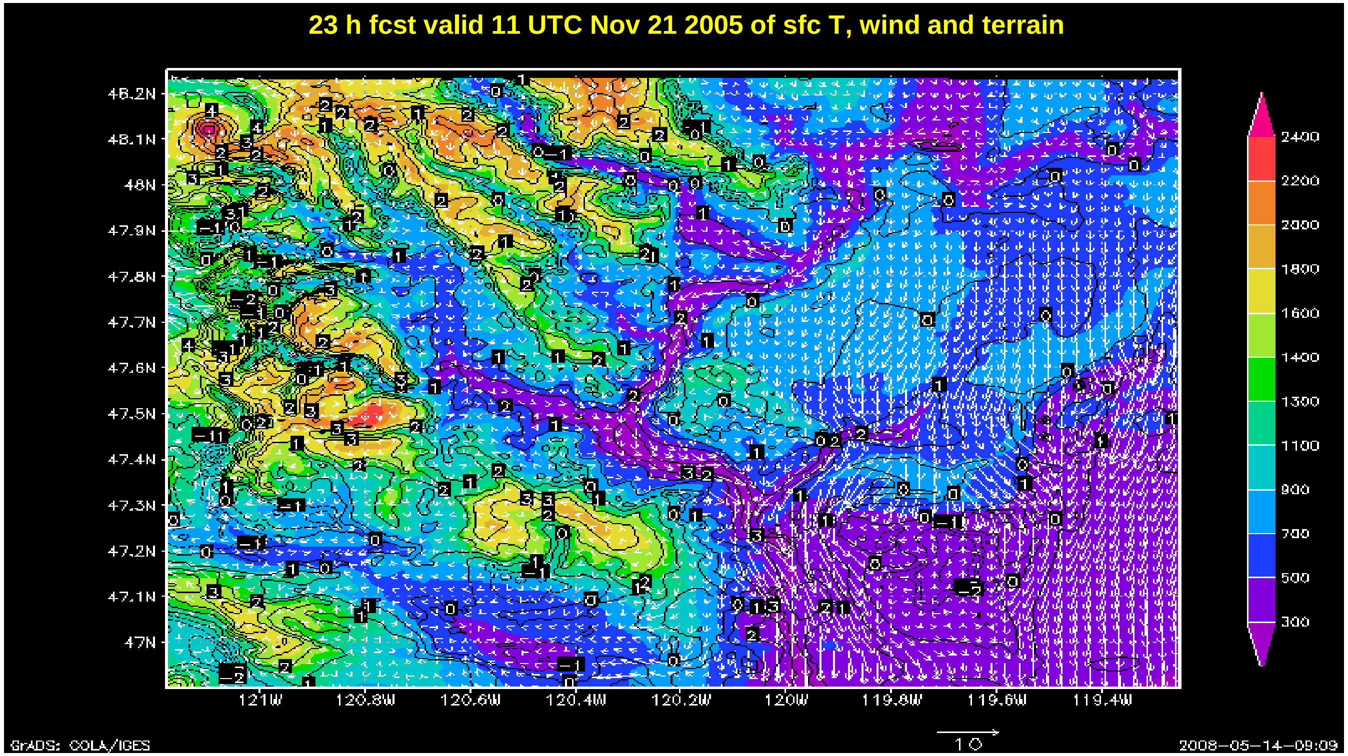
WRF-ARW runs over the Columbia River Basin in WA for CRREL

1 km grid spacing/ nest 2



1 km domain, 90 vertical levels, YSU pbl option, WSM5 microphysics, diffusion on Cartesian surfaces

* No FDDA applied to this case simulation

Classic stable PBL problem (but difficult to accurately resolve numerically) that the Army often encounters called "Cold Pooling", which can lead to many days of cold & damp conditions with low overcast and fog (and sometimes as in this scenario, icing and riming of surfaces due to light precipitation/freezing drizzle) in large valleys/basins

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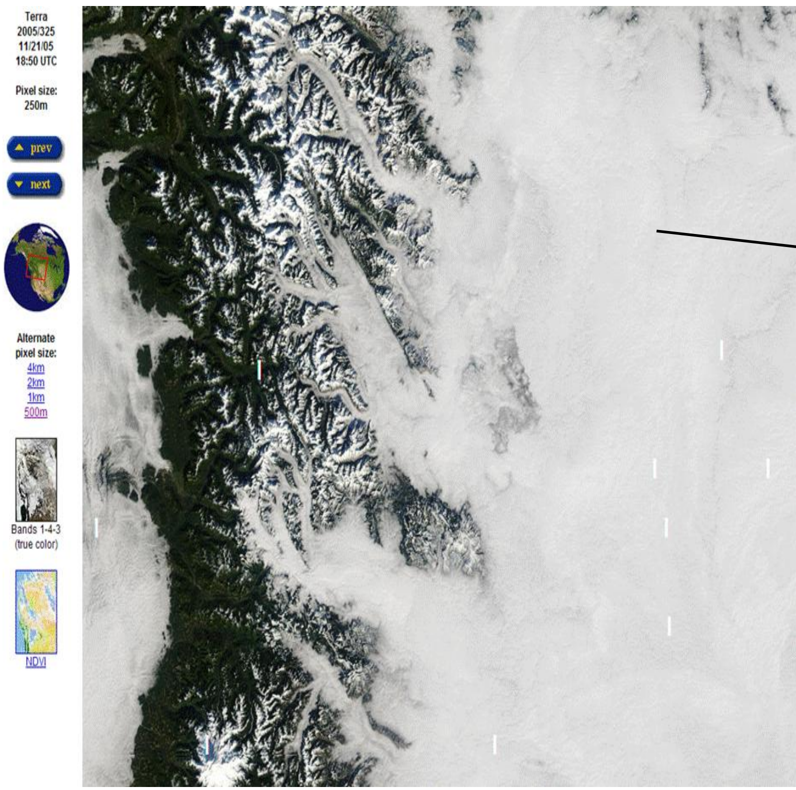
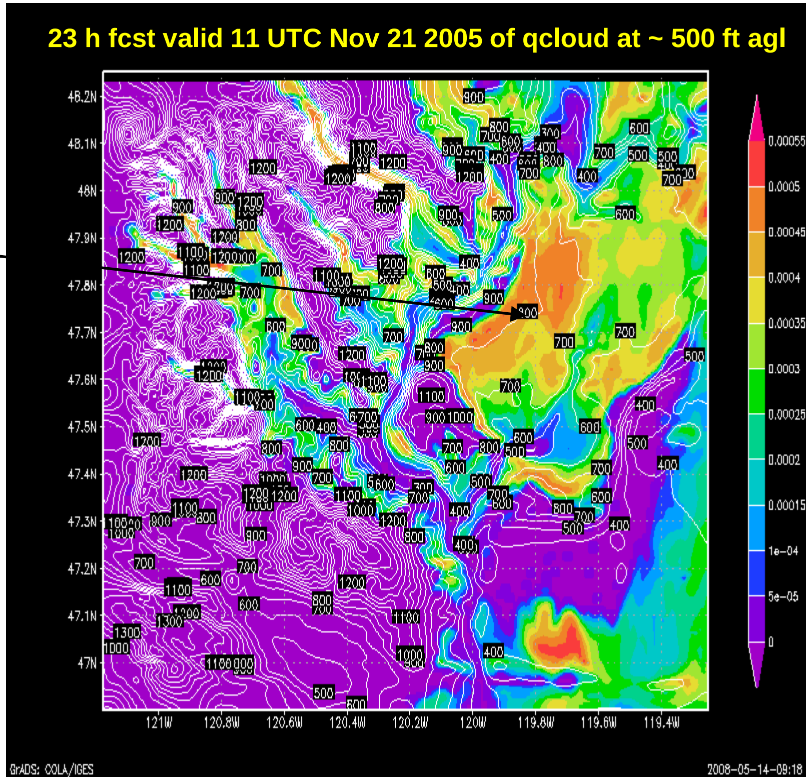
WRF-ARW runs over the Columbia River Basin in WA for CRREL



Satellite fog & low cloud field captured from TERRA for the region near Wenatchee, WA (~ 18 UTC Nov 21 2005)



The extended 1 km nest domain, along with the more complex microphysics, diffusion option, and vertical resolution combined to provide a much more realistic low cloud forecast on Nov 21 (as compared to original 60 level version, which greatly underforecast the low cloud and fog extent).

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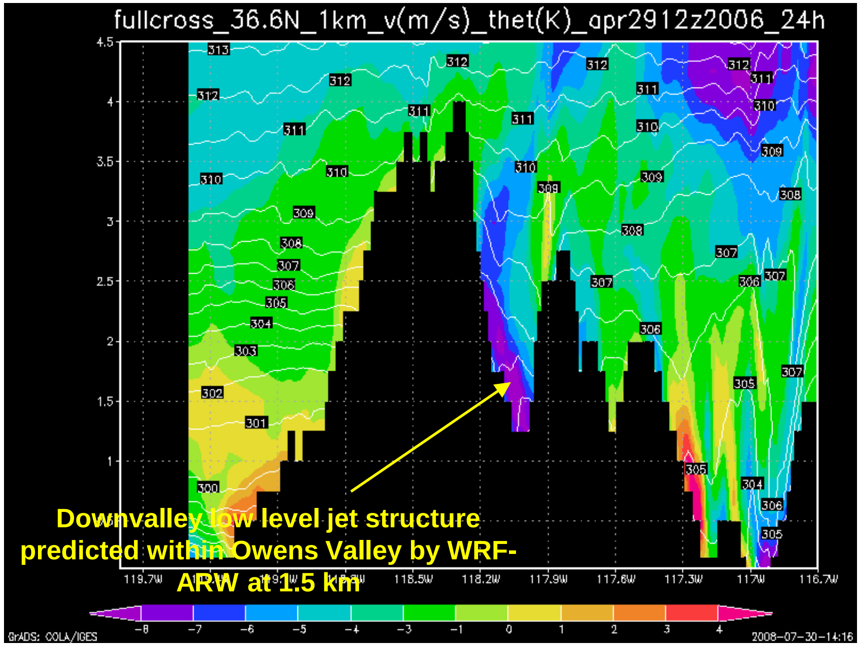
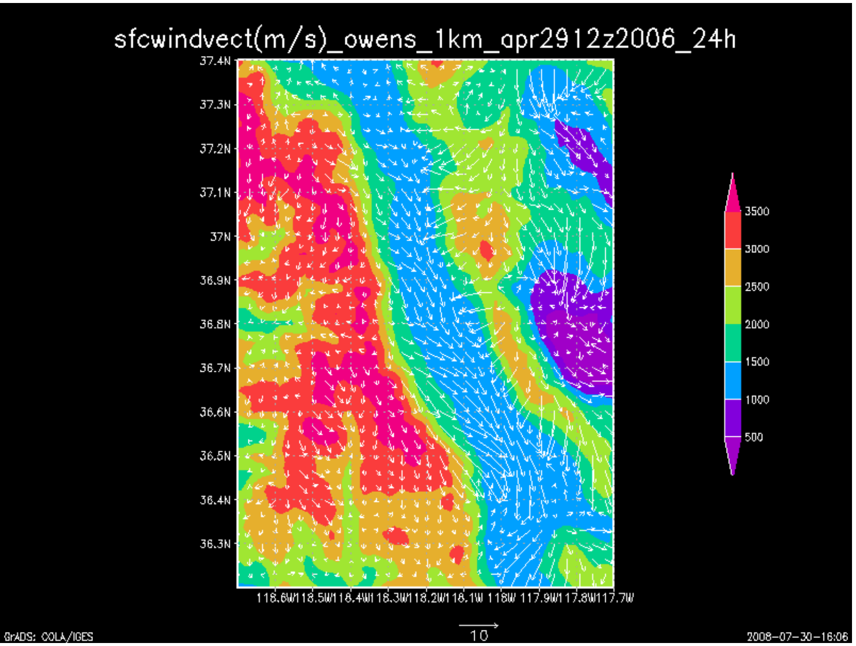
T-REX stable PBL simulations

Research partly funded by DTRA/ARO SBL Center

Valley and other small-scale wind systems and BL phenomena are of great interest to Army operations in complex terrains, but they tend to contain much variability and localization missed by operational models at Centers. Numerical models can handle the mean details of such flow systems quite well, however, given adequate horizontal terrain/land use resolution and vertical resolution.



Modeling of diurnal BL structures within a large rift valley (Owens Valley, CA) & under benign synoptic conditions, during Extended Observing Period 4 of the Terrain-induced Rotor Experiment (T-REX) of 2006



*** Collaborating with Dr. Sen Chiao (Florida Institute of Technology) & Dr. Ed Colon (NCEP/SAIC)**

* No FDDA applied to T-REX simulations

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DPG, UT MODELING DOMAINS

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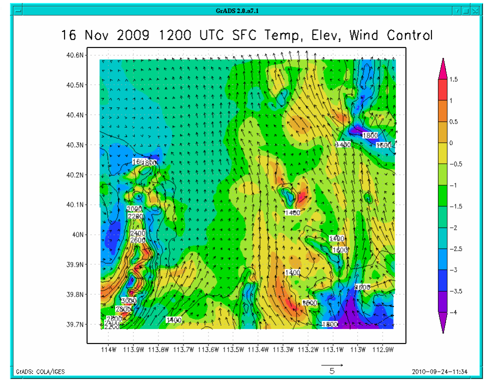
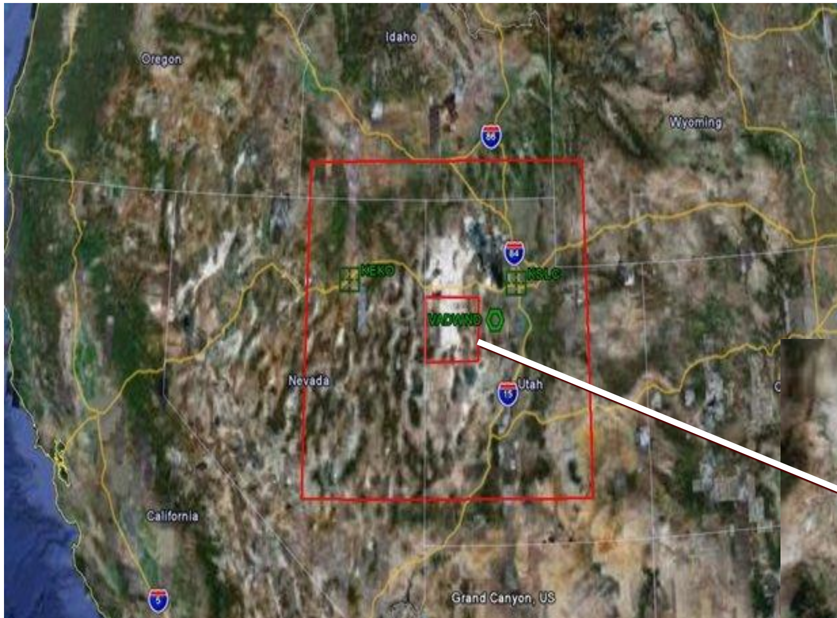
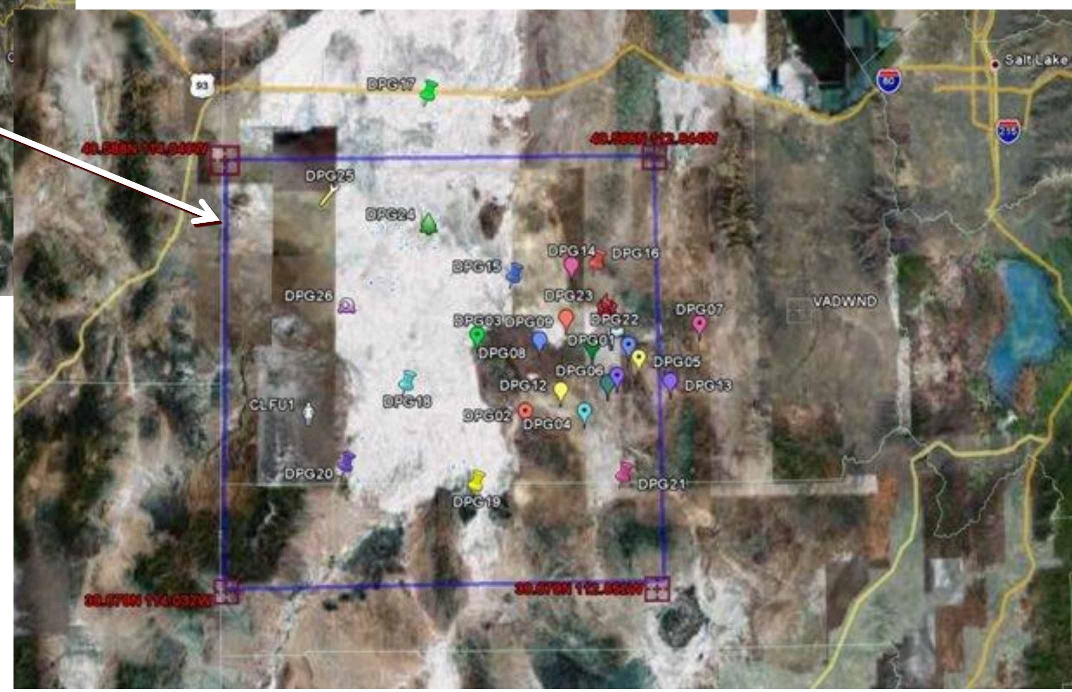


Investigate different PBL physics, microphysics, time steps and vertical levels over select case study days



Nested Domains over DPG, UT

Outer Domain = 546km x 546km
Inner Domain = 102km x 102km



Inner Domain over DPG, UT

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WRE-N FDDA investigations using TAMDAR data on Aerostar UAS at LRU Airport

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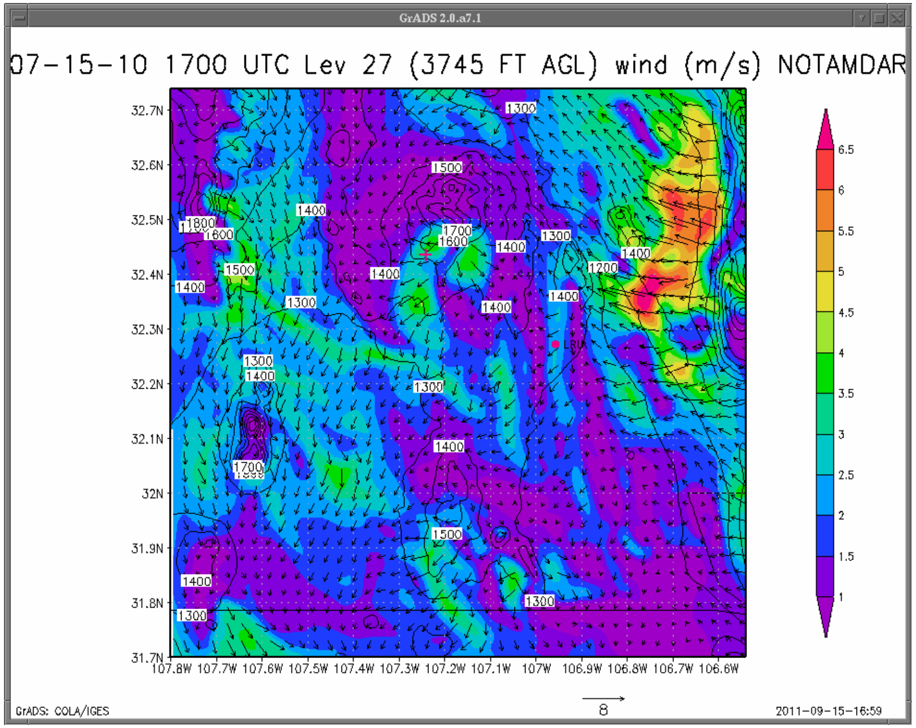
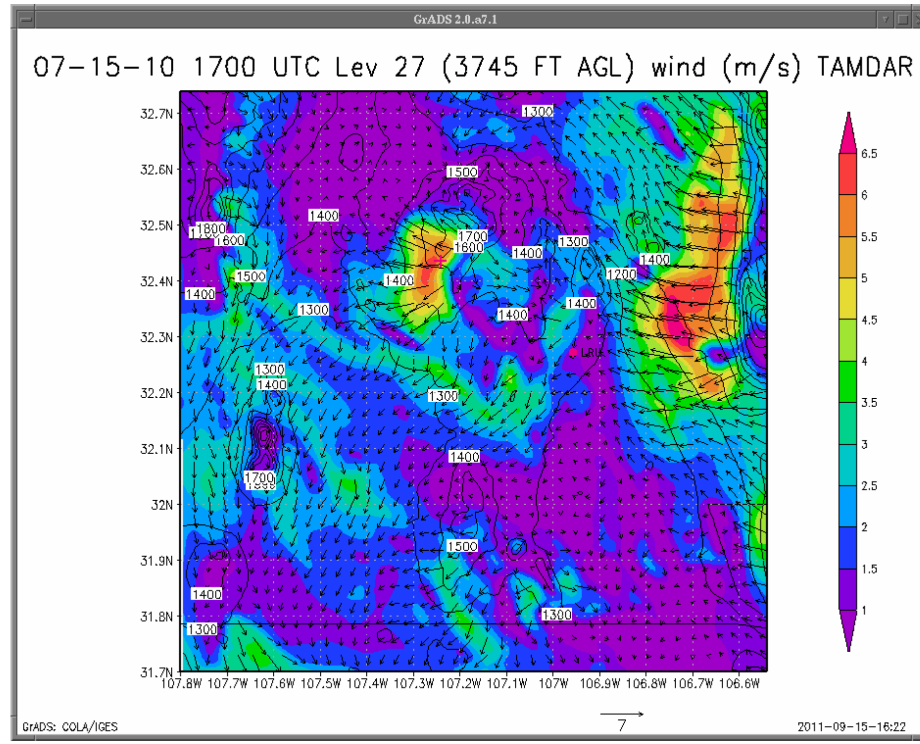


No TAMDAR FDDA



TAMDAR FDDA

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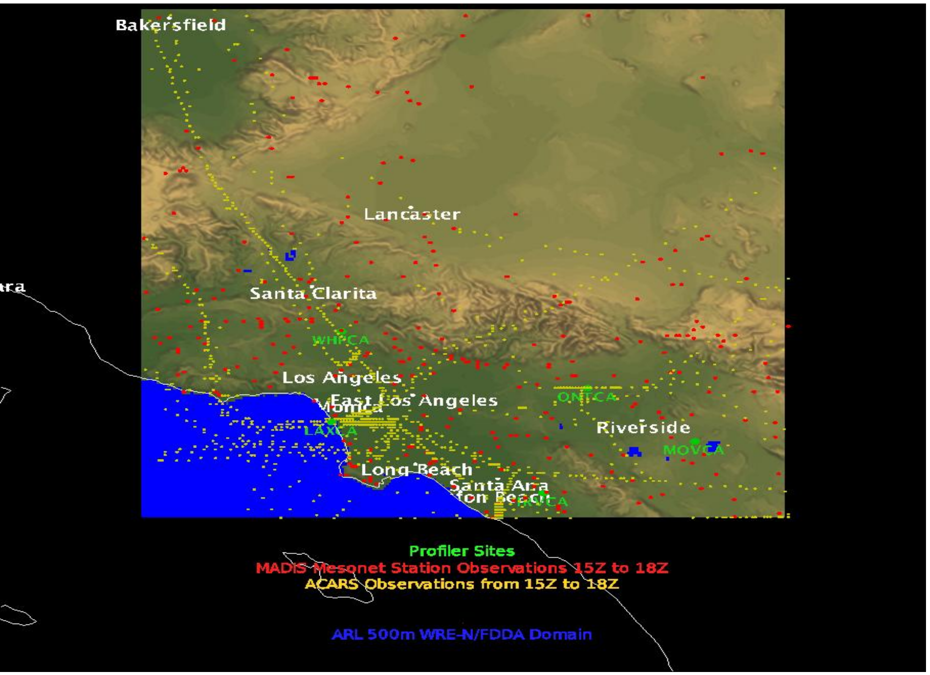
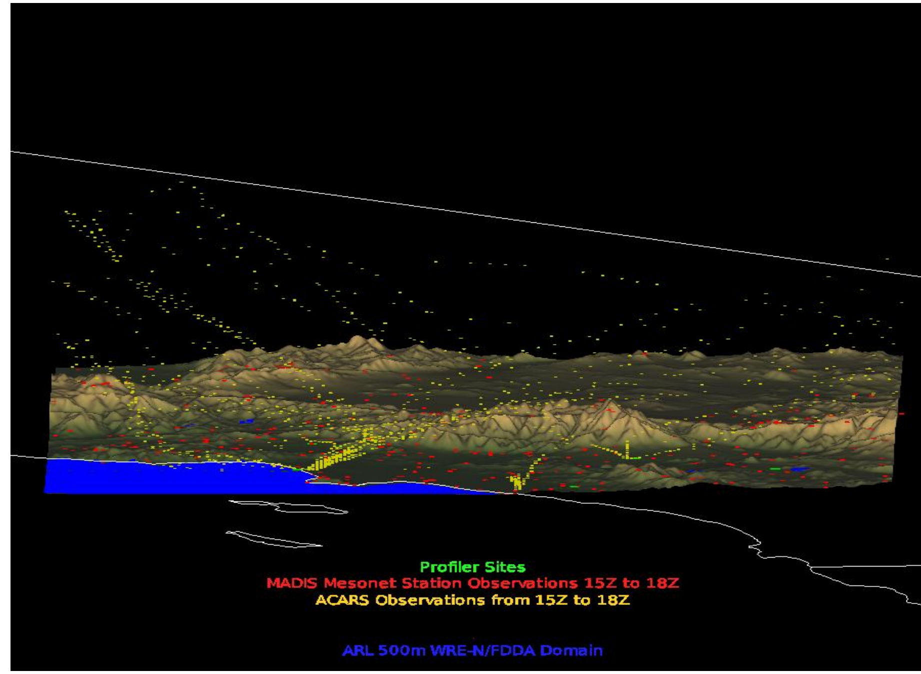
WRE-N FDDA investigations over S CA





-Ongoing studies over S CA CONUS domain investigating FDDA in WRE-N configurations down to 0.5 km

- Ingest of surface (metar, ship/buoy, mesonet), radiosonde/pibal, wind profiler, and aircraft (ACARS & TAMDAR) observations into observation nudging FDDA, and testing of cycling, observation QC and observation sensitivities for local nowcasting

-Testing using WRE-N grid output as input to ARL's diagnostic 3DWF wind model running at <= 100 m grid spacing

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